MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2021/2022

PTH0016 MODERN PHYSICS AND THERMODYNAMICS

(Foundation in Engineering)

8 AUGUST 2022
9:00 A.M. – 11:00 A.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 6 pages, excluding the cover page.
2. Answer all questions.
3. Write your answers on answer sheets given.
4. Show all relevant steps to obtain maximum marks.

QUESTION 1 (15 MARKS)

a) A grating has a slit spacing of 1.5 μm. Light of wavelength 0.6 μm is incident normally on the grating.

i) Calculate the number of maxima that can be seen in the pattern on the screen. [1.5 marks]

ii) Calculate the distance of all maxima from the central maximum if the screen is 3.0 m from the grating. [3.5 marks]

iii) Sketch the pattern. Label all maxima and their distance from the central maximum. [2 marks]

b) A laser beam is travelling inside a slab. The slab is in the air. When the laser beam encounters a boundary with air, the angle of reflection is 20.0° and the angle of refraction is 38.0°.

i) Calculate the index of refraction of the slab. [1.5 marks]

ii) Determine the speed of light in the slab. [1.5 marks]

iii) At what minimum angle of incidence would the light be totally internal reflected? [1.5 marks]

c) A 4.0 cm high object, when placed at a certain distance in front of a concave mirror, produces an upright image 8.5 cm high, 32.0 cm from the mirror.

i) Determine the position of the object relative to the mirror. [2 marks]

ii) Calculate the focal length of the mirror. [1.5 mark]

QUESTION 2 (10 MARKS)

a) Explain briefly why no electrons are emitted when intense light below a certain frequency falls on a metal but a weak light above this frequency readily causes the emission of electrons. [2 marks]

b) **Figure Q2(a)** shows a set-up of experiment in Quantum Physics.

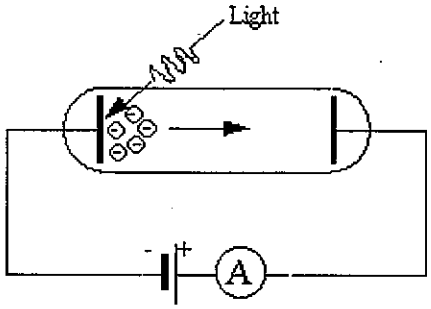


Figure Q2(a)

i) What can be observed from ammeter? [1 mark]

ii) What is the requirement of light frequency in order to achieve the outcome for this experiment? [1 mark]

Continued...

iii) Given the work function of the metal is $w_o = 5.5$ eV and it is found that stopping potential of the same metal is 4.5 V, calculate the frequency of the incoming light.

[2 marks]

c) What needs to be done to the electron so that it can move from level n = 3 to n = 4 in an atom?

[1 mark]

d) Consider the energy level diagram of a hydrogen atom shown in **figure Q2(b).** Calculate the frequency and the wavelength of the photons emitted in A.

[3 marks]

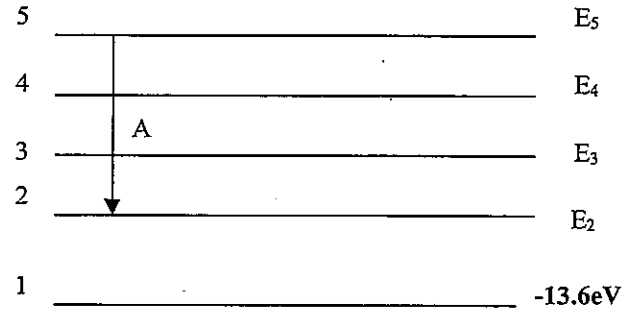


Figure Q2(b)

QUESTION 3 (10 MARKS)

a) The last step in the carbon cycle that takes place inside stars is $p + {}^{15}_{7}N \rightarrow {}^{12}_{6}C + (?)$. This step releases 5.00 MeV of energy.

i) Show that the reaction product "(?)" must be an alpha particle.

[1 mark]

ii) Calculate the atomic mass of reaction product "(?)" from the information given.
(Atomic mass: ${}^{15}_{7}N$ = 15.000109 u, ${}^{1}_{1}p$ =1.007825 u, ${}^{12}_{6}C$ = 12.000000 u)

[2 marks]

b) Radon (Rn) is a gas with a half-life of 3.83 days. In a 1.25 mg sample of pure radon-222,

i) how many nuclei are present initially?

[2 marks]

ii) how many nuclei will remain after 10.0 days?

[1.5 marks]

iii) what is the activity after 10.0 days?

[1.5 marks]

iv) approximately, how long will it take for 90% of the sample to decay?

[2 marks]

Continued...

QUESTION 4 (15 MARKS)

a) Define the following terms:

i) Thermal equilibrium [1 mark]

ii) First law of thermodynamics [1 mark]

iii) Conduction [1 mark]

iv) Specific heat capacity [1 mark]

v) Isothermal changes [1 mark]

b) A square Pyrex plate is 18 cm on each side at $30°C$. If the coefficient of linear expansion of Pyrex is $0.30 \times 10^{-5}\ K^{-1}$,

i) what is its new size (area) if it is heated to $80°C$?

[2.5 marks]

ii) what will be the temperature if its new length is 18.001 cm?

[1.5 marks]

c) 7200 J of heat is required to change m_{ice} kg of ice at $0°C$ to steam at $100°C$. Calculate the value of m_{ice}.

Given the latent heat of fusion of ice at $0°C$ is 333.70 $kJkg^{-1}$, the specific heat capacity of water is 4186 $kJkg^{-1}K^{-1}$ and the latent heat of vaporization of water at $100°C$ is 2256 $kJkg^{1}$.

[3 marks]

d) 2.50 L of an ideal gas at $20°C$ is heated and expanded at a constant pressure of 5 atm. As its temperature increased to $127°C$,

i) calculate the new volume of the gas

[1.5 marks]

ii) how much work is done by the gas?

[1.5 marks]

End of paper.

APPENDIX

LIST OF PHYSICAL CONSTANTS

Electron mass,	m_e	=	9.11×10^{-31} kg
Proton mass,	m_p	=	1.67×10^{-27} kg
Neutron mass,	m_n	=	1.67×10^{-27} kg
Magnitude of the electron charge,	e	=	1.60×10^{-19} C
Universal gravitational constant,	G	=	6.67×10^{-11} N m^2 / kg^2
Universal gas constant,	R	=	8.314 J/mol K
Hydrogen ground state,	E_0	=	13.6 eV
Boltzmann's constant,	k_B	=	1.38×10^{-23} J/K
Compton wavelength,	λ_c	=	2.426×10^{-12} m
Planck's constant,	h	=	6.63×10^{-34} J s
		=	4.14×10^{-15} eV s
Speed of light in vacuum,	c	=	3.00×10^8 m/s
Rydberg constant,	R_H	=	1.097×10^7 m^{-1}
Acceleration due to gravity of earth,	g	=	9.80 m/s^2
1unified atomic mass unit,	1 u	=	931.5 MeV/c^2
		=	1.66×10^{-27} kg
1 electron volt,	1 eV	=	1.60×10^{-19} J
Avogadro's number,	N_A	=	6.02×10^{23} mol^{-1}
Threshold of intensity of hearing,	I_0	=	1.0×10^{-12} W/m^2
Coulomb constant,	$k = \frac{1}{4\pi\varepsilon_0}$	=	9.0×10^9 N m^2 /C^2
Permittivity of free space,	ε_0	=	8.85×10^{-12} C^2/N m^2
Permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ T m/A
1 atmosphere pressure,	1 atm	=	1.013×10^5 N/m^2
		=	1.013×10^5 Pa
Wien's displacement constant		=	2.90×10^{-3} mK
Speed of sound in air		=	343 m/s
Refractive index of air/vacuum	n	=	1.0
Earth: Mass,	M_E	=	5.97×10^{24} kg
Radius (mean),	R_E	=	6.38×10^3 km
Moon: Mass,	M_M	=	7.35×10^{22} kg
Radius (mean),	R_M	=	1.74×10^3 km
Sun: Mass,	M_S	=	1.99×10^{30} kg
Radius (mean),	R_S	=	6.96×10^5 km
Earth-Sun distance (mean),		=	149.6×10^6 km
Earth-Moon distance (mean),		=	384×10^3 km
First Bohr Raduis,	a_o	=	0.053 nm

LIST OF FORMULAS

$$\sin\theta_1 + \sin\theta_2 = 2\sin\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\cos\theta_1 + \cos\theta_2 = 2\cos\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\sin\left(\theta+\frac{\pi}{2}\right) = \cos\theta$$

$\sin\theta \approx \tan\theta \approx \theta$ *rad* for small angles

$D(x, t) = D_M \sin(kx \pm \omega t \pm \phi)$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n = c/v$$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$$v = \sqrt{\frac{F_T}{\mu}} \qquad v = \sqrt{\frac{\text{elastic property of the medium}}{\text{inertia property of the medium}}} \qquad v = (331 + 0.60T) \qquad v = f\lambda$$

$$f_n = \frac{nv}{2L} \qquad f_n = \frac{nv}{4L} \qquad \lambda_n = \frac{2}{n}L \qquad f' = f\left(\frac{v \pm v_o}{v \mp v_s}\right)$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{f} = (n-1)\left\{\frac{1}{R_1} + \frac{1}{R_2}\right\} \qquad f = \frac{R}{2} \qquad M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$d\sin\theta = m\lambda = dy/L \qquad d\sin(\theta) = \left(m+\frac{1}{2}\right)\lambda \qquad a\sin(\theta) = n\lambda$$

$$\lambda_m . T = 0.2898 \times 10^{-2} \qquad I(\lambda, T) = \frac{2\pi c k_B T}{\lambda^4} \qquad eV_s = hf - w_o \qquad hf = hc/\lambda$$

$$E_n = -\frac{mk^2e^4}{2\hbar^2}\left(\frac{1}{n^2}\right) \qquad r_n = \frac{\hbar^2}{mke^2}n^2 \qquad L = mvr_n = n\hbar$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right] \qquad \frac{1}{\lambda} = \frac{mk^2Z^2e^4}{4\pi c\hbar^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] \qquad \lambda = \frac{h}{p}$$

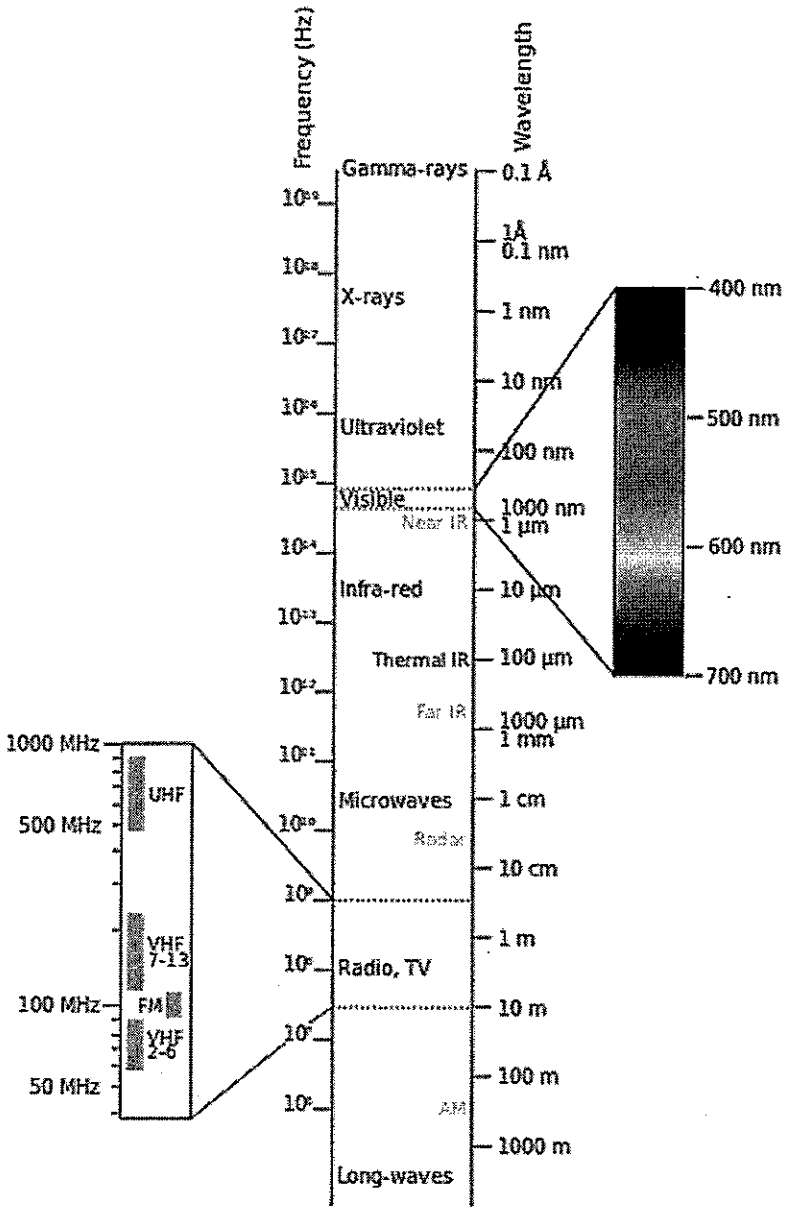
$$R = R_0 e^{-\lambda t} \qquad \lambda = \frac{\ln 2}{T_{1/2}} \qquad Q = (M_X - M_Y - M_\alpha)\,c^2 \qquad R = \lambda N$$

$$pV = nRT \qquad k = \frac{R}{N_A} \qquad N = N_0 e^{-\lambda t} \qquad N_0 = nN_A$$

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta L} \qquad \frac{\Delta Q}{\Delta t} = e\sigma AT^4 \qquad \frac{\Delta Q}{\Delta t} = IeA\cos(\theta) \qquad \Delta L = \alpha\Delta T L_o$$

$$\overline{KE} = \frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT \qquad U = \frac{3}{2}nRT \qquad Q = mc\Delta T$$

$$Q = \Delta U + W \qquad W = \int dW = \int_{V_i}^{V_f} P\,dV \qquad W = P\Delta V$$


Frequency (Hz)
Wavelength
Gamma-rays
0.1 Å
1Å
0.1 nm
X-rays
1 nm
10 nm
Ultraviolet
100 nm
Visible
1000 nm
Near IR
1 µm
Infra-red
10 µm
Thermal IR
100 µm
Far IR
1000 µm
1 mm
Microwaves
1 cm
Radar
10 cm
1 m
Radio, TV
10 m
100 m
AM
1000 m
Long-waves
400 nm
500 nm
600 nm
700 nm
1000 MHz
500 MHz
100 MHz
50 MHz
UHF
VHF 7-13
FM
VHF 2-6